# APPENDIX F

## Temperature Conditions in the Lower Boise River

**DRAFT**

# Water Temperatures in the Lower Boise River: Conditions and Sources

6/6/98

Prepared for
The State of Idaho

by
The Idaho Division of Environmental Quality, Boise Regional Office

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# Summary of Conclusions

- Two segments of the Boise River, Star to Notus and Notus to the Snake River, have temperature as a pollutant on the 1996 303(d) list. The segment of the River from Star to Notus is designated for cold water biota along its entire length, and for salmonid spawning (mountain whitefish) from Star to Caldwell. The segment from Notus to the Snake River is designated for cold water biota along its entire length.

- Along the segment that extends from Star to Notus, water temperatures meet the daily maximum criterion for salmonid spawning (13 deg C). The daily average criterion for salmonid spawning cannot be evaluated, since all available data are either single measurements, or are outside of the October 15 to March 15 time period.

- From Star to the Snake River, the available data indicate that water temperatures are occasionally in excess of state maximum (22 deg C) and average (19 deg C) criteria for cold water biota at Middleton. The frequency of water temperatures in excess of the cold water biota criteria increases at Caldwell, and increases further at Parma. The last few miles of the river exceed both the maximum and the average criteria for cold water biota every July and August from 1987 to 1997 (except 1995, for which no data are available).

- Site specific, seasonal water temperature criteria may be required for the lower Boise River downstream of Middleton.

## Sources

- Tributary inputs contribute only minor temperature increases during the months when state criteria are not met.

- Atmospheric sources of temperature contribute the majority of the thermal inputs that raise water temperatures above state criteria.

- The tributaries and point source inputs to the river between Middleton and Parma would have to be cooled by 5 to 6.5 degrees Celsius to prevent daily maximum temperature criteria exceedences at Parma.

- The tributaries and point source inputs to the river between Middleton and Parma would have to be cooled by 7.0 to 11.0 degrees Celsisus to prevent daily average temperature criteria exceedences at Parma.

# Introduction

The temperature of the water in the lower Boise River is only one element of the overall water quality, and may have an influence over the use of the river by swimmers, fish, and aquatic macroinvertebrates. The Boise River contains a wide varitey of fish, including rainbow and brown trout upstream of Star and mountain whitefish from Lucky Peak Dam to the confluence with the Snake River. Other species that are present include dace, redside shiners, suckers, and smallmouth bass. The Division of Environmental Quality (DEQ) applies daily maximum and daily average criteria to water temperatures. In the Boise River, two sets of criteria apply, one for cold water biota, the other for salmonid spawning and rearing. This document provides a review of Boise River water temperatures on 303(d) listed stream segments with respect to applicable criteria, and analyzes the sources of thermal inputs to the river.

# Segments of the River Listed for Temperature

Two segments of the Boise River have temperature listed as a pollutant on the 1996 303(d) list for Idaho. The first segment extends from Star to Notus, while the second extends from Notus to the Snake. Figure 1 shows a map of the lower Boise River watershed, and indicates which segments of the Boise River are listed for temperature on the 1996 303(d) list. The Boise River has water temperature criteria applicable to segments designated for salmonid spawning, as well as for cold water biota. The water temperature criteria for cold water biota and salmonid spawning are shown in Table 1, below.

**Table 1. Water Temperature Criteria**

| Criteria | Cold Water Biota | Salmonid Spawning |
|---|---|---|
| Daily Maximum | 22 deg C. | 13 deg C. |
| Maximum Daily Average | 19 deg C. | 9 deg C. |

The cold water biota criteria apply from Lucky Peak Dam to the Snake River, including the two river segments listed for temperature downstream of Star. Salmonid spawning criteria apply from Diversion Dam to Caldwell, and include part of the segment from Star to Notus that is listed for temperature. Since mountain whitefish are the only salmonids known to inhabit the Boise River downstream of Star, the water temperature criteria for spawning apply from October 15 to March 15.

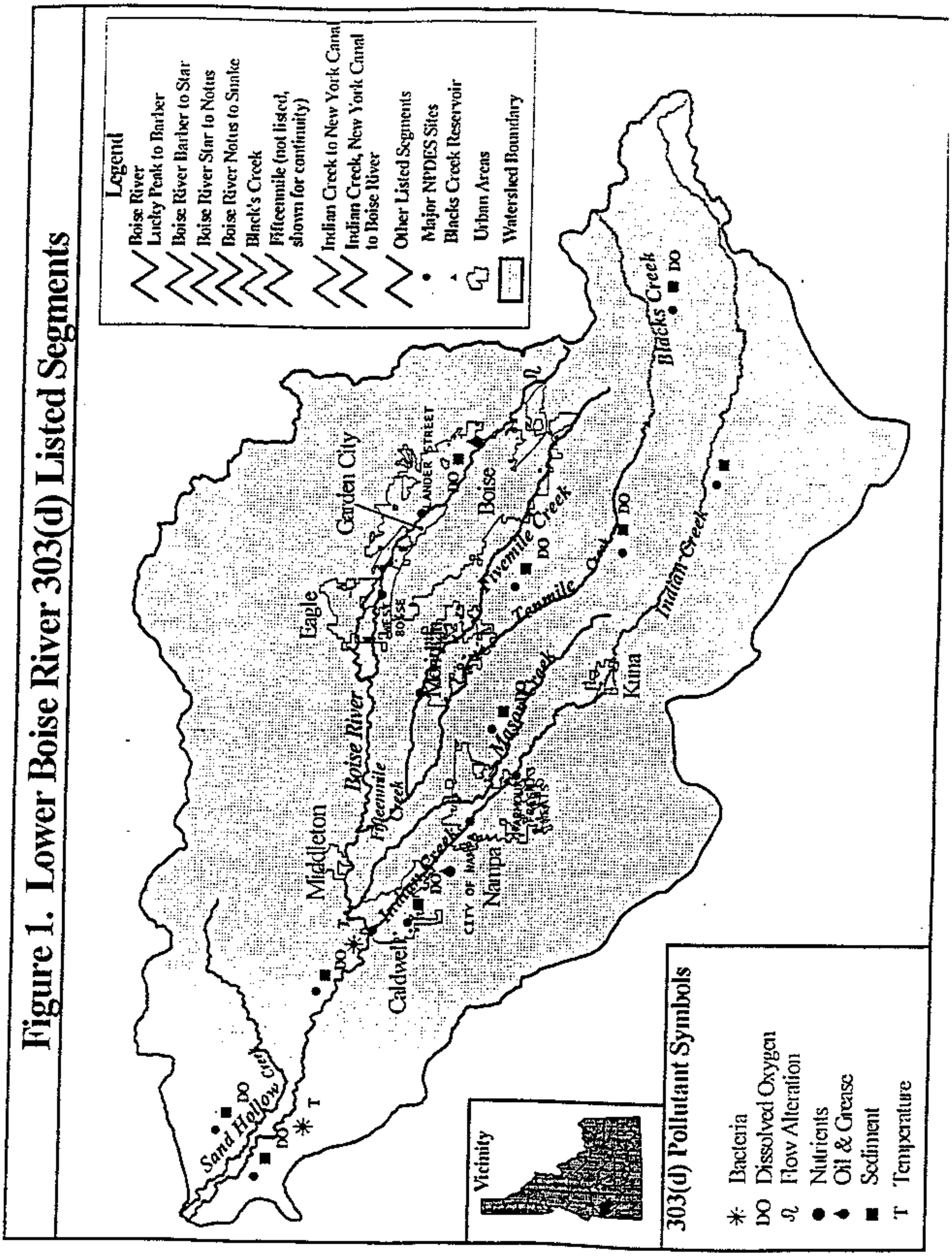


Figure 1. Lower Boise River 303(d) Listed Segments

# Scope and Purposes of the Analysis

The analysis of water temperatures in the lower Boise River is designed to assess recent temperature conditions and compare those conditions to State criteria. For segments of the river in which temperature criteria are not met, DEQ identifies the sources affecting water temperature in the river, both natural and human. The primary focus of the analysis is on the two segments listed for temperature, but includes the two segments upstream of Star as sources of temperature. The document does not review temperatures with respect to state criteria on the two river segments upstream of Star.

# Water Temperature Conditions and State Criteria

## Available Data

The sources of water temperature data available for analysis in the lower Boise River include synoptic monitoring by the USGS at Diversion Dam, Glenwood Bridge, Middleton, at the mouths of major tributaries, and at Parma. The USGS also has long term monitoring data at Parma from 1986 through 1995. During the July and August of 1996, the USGS collected hourly temperature data in the Boise River at Barber Park, Glenwood Bridge, Middleton, Caldwell, Parma, Dixie Drain, and Conway Gulch. Hourly temperature data are now available during 1997 at sites including Diversion Dam, Glenwood, Middleton, Willow Creek, Caldwell, Conway Gulch, Dixie Drain, and Parma.

The data available at Parma are extensive and describe temperature conditions in both low flow, dry years, and high flow, cooler years. The data available at Diversion Dam, Glenwood Bridge, Middleton, Caldwell, and in the tributaries are more sparse, but are still useful for the analysis. Unfortunately, the hourly data collected at Diversion Dam and Glenwood Bridge do not include a very hot, low flow year, making it difficult to assess the impacts of Boise waste water on the river at worst case conditions. Hourly temperature monitoring at Middleton, Caldwell, and in selected tributaries during 1996 and 1997 is especially helpful, as shown later in the source analysis. The available data are summarized in a table attached as Appendix A.

USGS gage stations at Glenwood Bridge, Middleton, and Parma provide daily flow data for the Boise River. In addition, the Idaho Department of Water Resources (IDWR) has estimates of the daily flows from all major lower Boise River tributaries. Daily irrigation diversion flows are from IDWR publications.

## Data Gaps

The two significant data gaps are evident with respect to water temperatures downstream of Middleton. First, data are need to characterize the daily average and daily maximum water temperatures in the Boise River between Middleton and Caldwell during the October 15 to March 15 spawning time period. Second, daily average maximum effluent temperature data for the Caldwell waste water treatment plant are needed to improve the accuracy of the analysis described below.

## Salmonid Spawning Criteria from Star to Caldwell

The only data available to evaluate against the salmonid spawning water temperature criteria are the USGS synoptic monitoring data for Middleton that fall within the range of dates from October 15 to March 15. The hourly data collected at Middleton and Caldwell in 1996 and 1997 are all outside of the spawning time period, and thus are not pertinent to this analysis. None of the measured temperatures are greater than 13 degrees Celsius. Since the synoptic data include only one measurement per day, the daily average criterion, 9 degrees C, cannot be evaluated. In addition, since the synoptic sampling events do not necessarily coincide with the highest water temperature of the day, the data cannot be used to evaluate compliance with the daily maximum criterion.

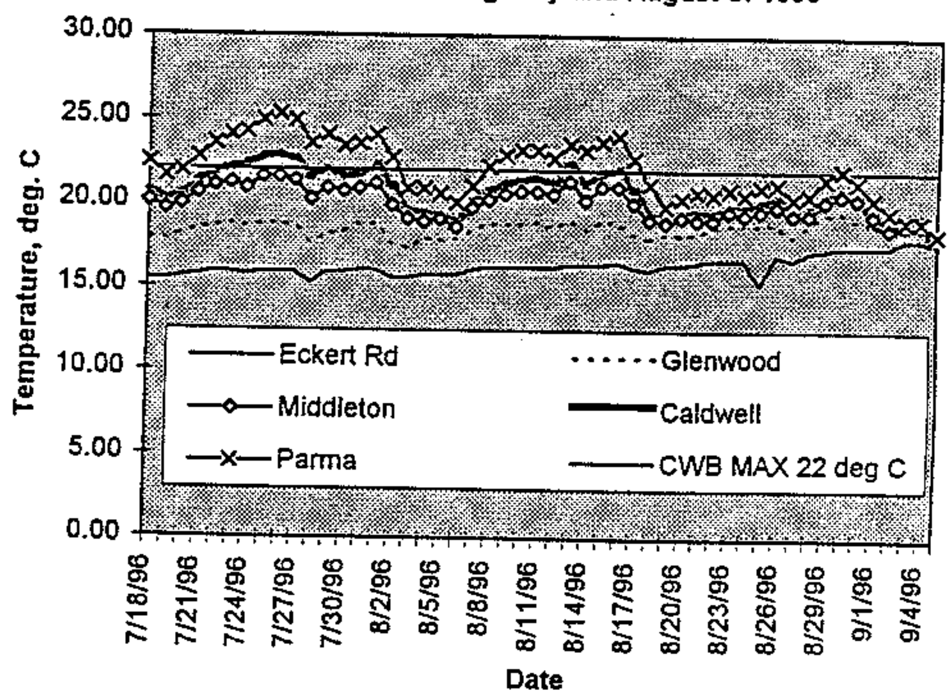
## Salmonid Spawning Criteria from Caldwell to Parma

Salmonid spawning for mountain whitefish is an existing, though undesignated use in the the Boise River downstream of Caldwell. As noted above, the time period designated to protect whitefish spans October 15 to March 15. In daily data from the river near Parma from 1987 through 1995, the water temperatures exceed the daily maximum limit from one to twelve times per month during October, depending on the year. The water temperatures at Parma also exceed the daily maximum limit in the first two weeks of March during hot, dry years (1992 and 1994). The total number of days on record with water temperatures greater than 13 degrees at Parma is 50, out of 1389 spawning days monitored from 1986 to 1997. The daily maximum water temperature exceedences represent 3.5 percent of the total days, and are clustered at the beginning and the end of the October 15 to March 15 time period. The daily average water temperatures in the Boise River near Parma are warmer than 9 degrees Celsius (the salmonid spawning daily average criterion) on 258 of 1389 spawning days monitored, or 18.5 percent of the total days. The daily average criteria exceedences are clustered in October, November, February, and March. Only two salmonid spawning daily average criteria exceedences occurred during December and January.

## Water Temperatures Greater than Cold Water Biota Criteria

The water released from Lucky Peak dam has a fairly stable temperature during the summer time, because the water leaves the reservoir through deep penstocks. As the water moves downstream, it gradually becomes warmer, and its temperature fluctuates more widely over time. Figure 2 shows the daily maximum water temperatures at different locations in the river. The peaks and valleys are specific to 1996, but the relative positions of each site are the same from year to year. When water arrives at Parma, it is significantly warmer than the other four upstream stations, and is often warmer than the cold water biota maximum criterion during July and August. The daily average values shown in Figure 3, on the following page, show a similar pattern.

Figure 2. Daily Maximum Temperatures in the Lower Boise River during July and August of 1996



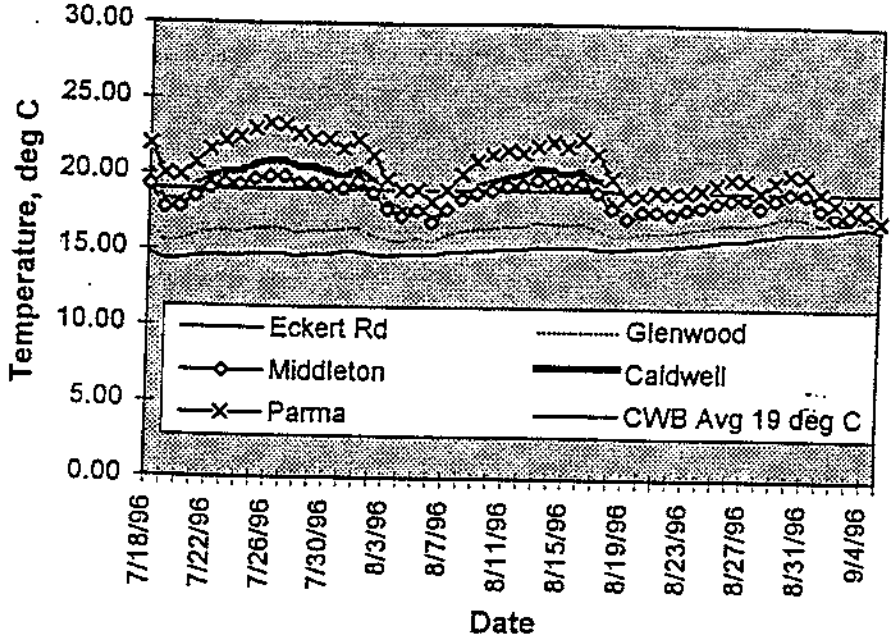
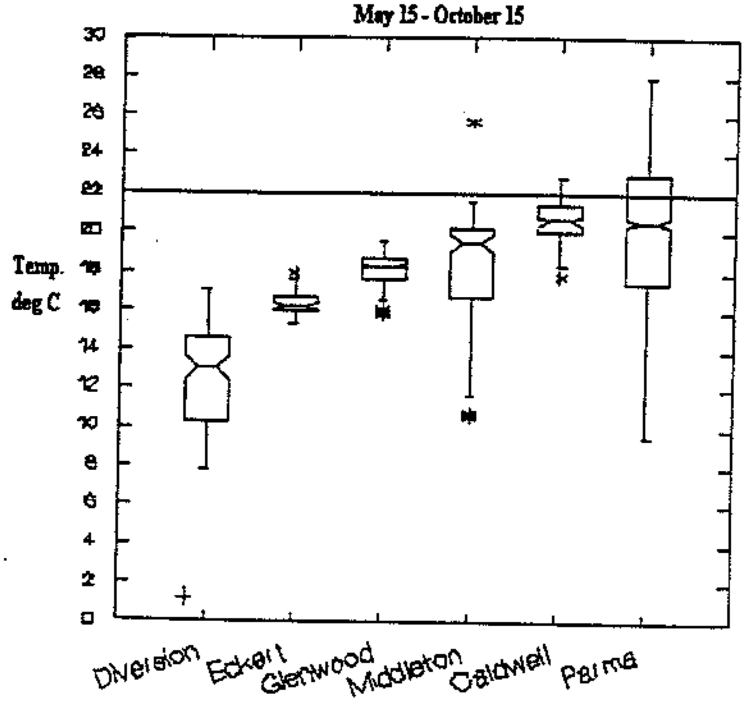



**Figure 3. Daily Average Temperatures in the Lower Boise River Watershed, July and August, 1996**

From the upstream end of the watershed, at Lucky Peak Dam, to the lower end of the Boise River near Parma, water temperatures increase quite significantly. Figure 4 shows box plots of daily maximum water temperatures from May through October at various stations in the Boise River. The notches on the boxes represent the 95% confidence around the median values (the center line of the box). Since, the confidence intervals for Diversion Dam, Eckert Road, Glenwood Bridge, Middleton, and Parma do not overlap, the differences between their medians are statistically

Figure 4. Daily Maximum Water Temperatures in the Lower Boise River
May 15 - October 15




significant. The median temperatures at Caldwell and Parma may not be significantly different at the 95% confidence level. A guide to interpreting boxplots is located at the back of the document in Appendix D.

## Middleton

The water temperature data available at Middleton are very good for 1996 and 1997, but are sparse prior to 1996. The data are not sufficient to fully evaluate water quality criteria at Middleton during hot, low flow years such as 1992. Water temperatures at Middleton do not always meet the daily average criterion of 19 degrees C. Only one exceedence of the daily maximum criterion occurred at Middleton from 1994 to 1997. Figures One and Two in Appendix B display water temperatures at Middleton. The exceedences by month are summarized in Table 2, below.

**Table 2. Review of Temperature Criteria at Middleton, 1996 - 1997**

| Total by Month 1996 and 1997 | Exceed Daily Maximum 22 deg C. | Exceed Daily Average 19 deg C. |
|---|---|---|
| May | 0 | 0 |
| June | 0 | 0 |
| July | 0 | 13 |
| August | 0 | 10 |
| September | 0 | 0 |
| Grand Total, 1996 - 1997 n = 189 | 0 | 23 |

### Caldwell

During July and August of both 1996 and 1997, water temperatures at Caldwell exceed the daily maximum and average criteria more frequently than at Middleton. The water temperatures observed at Caldwell are displayed in Figures Three and Four of Appendix B. Table 3 contains a summary of criteria exceedences at Caldwell.

**Table 3. Review of Temperature Criteria at Caldwell, 1996 - 1997**

| Total by Month, 96-97 | Exceed Daily Maximum 22 deg C. | Exceed Daily Average 19 deg C. |
|---|---|---|
| May | 0 | 0 |
| June | 0 | 0 |
| July | 11 | 32 |
| August | 1 | 30 |
| September | 0 | 0 |
| Grand Total, 1996 - 1997 n = 116 | 12 | 62 |

## Parma

The water temperature at Parma is often significantly warmer than both of the state criteria for cold water biota during July and August of the past eleven years. June also has numerous water temperatures greater than the criteria. Occasional exceedences occur in May and September, but they are limited to the hottest year such as 1992 and 1994. The large grand totals listed in Table 4 are due in part to the fact that temperature has been measured longer at Parma than at Caldwell or Middleton. Figures Five and Six of Appendix B display the temperature data measured at Parma. Tables 5 and Table 6 show how the temperatures in excess of state criteria at Parma are distributed among the years of record.

**Table 4. Review of Temperature Criteria at Parma, 1987 - 1997**

| Total by Month, 87 - 97 | Exceed Daily Maximum 22 deg C. | Exceed Daily Average19 deg C. |
|---|---|---|
| May | 15 | 5 |
| June | 93 | 72 |
| July | 223 | 218 |
| August | 147 | 183 |
| September | 6 | 15 |
| Grand Total, 1987 - 1997<br>n = 3124 | 484 | 495 |

**Table 5. Daily Maximum Water Temperatures at Parma that Exceed 22 deg C, by Month and Year**

| Year | May | June | July | August | September | Totals |
|---|---|---|---|---|---|---|
| 1997 | 0 | 0 | 17 | 9 | 0* | 26 |
| 1996 | ND | ND | 12* | 13 | 0* | 25 |
| 1995 | 0 | 0 | 3* | 0 m | ND | 3 |
| 1994 | 2 | 15 | 29 | 23 | 0 | 69 |
| 1993 | 0 | 4 | 2 | 6 | 0* | 12 |
| 1992 | 3 | 20 | 26 | 21 | 2 | 72 |
| 1991 | 0 | 2 | 31 | 29 | 2 | 64 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1990 | 0 | 14 | 27 | 2* | ND | 43 |
| 1989 | 0 | 21 | 26 | 7* | 0 | 54 |
| 1988 | 3 | 17 | 30 | 22 | 0 | 72 |
| 1987 | 7* | ND | 20 | 14 | 2 | 43 |

*Missing Data, refer to data availability Table in Appendix A.
ND - No data

**Table 6. Daily Average Water Temperatures at Parma that Exceed 19 deg C, by Month and Year**

| Year | April | May | June | July | August | September | Totals |
|---|---|---|---|---|---|---|---|
| 1997 | 0 | 0 | 2 | 25 | 28 | 2 | 57 |
| 1996 | ND | ND | ND | 14* | 26 | 1* | 41 |
| 1995 | 0 | 0 | 0 | 4 | ND | ND | 4 |
| 1994 | 0 | 0 | 9 | 24 | 21 | 0 | 54 |
| 1993 | 0 | 0 | 4 | 1 | 10 | 0* | 15 |
| 1992 | 0 | 2 | 16 | 22 | 21 | 2 | 63 |
| 1991 | 0 | 0 | 1 | 30 | 30 | 2 | 63 |
| 1990 | 0 | 0 | 11 | 25 | 2* | ND | 38 |
| 1989 | 0 | 0 | 13 | 28 | 10* | 0* | 51 |
| 1988 | 0* | 0 | 16 | 29 | 25 | 0 | 70 |
| 1987 | 2 | 3* | ND | 16 | 10 | 2 | 33 |

*Missing Data, refer to data availability Table in Appendix A.
ND - No data

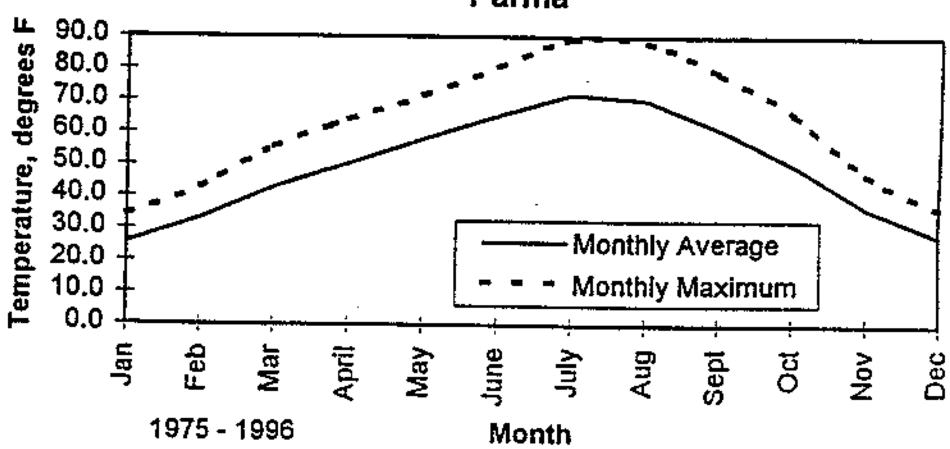
## Magnitude of Temperature Exceedences

Exceedences of the both the cold water biota daily maximum and daily average criteria occur at Parma regardless of flow conditions relative to the long term average for the site. In low flow, high temperature years such as 1991 the number of exceedences that occur in a month, as well as the magnitudes of those exceedences, increase. The exceedences in July of 1991 ranged from 22 to 26 degrees C., with the majority between 24 and 26 degrees C. Cooler, higher flow summers do not eliminate exceedences of cold water biota criteria, but they do reduce the frequency and magnitude of exceedences. For example, the water in the Boise River at Parma was warmer than 22 degrees Celsius on 17 days in July of 1997, but was warmer than 22 degrees during all 31 days of July in 1991. During July of 1997 at Parma, all 17 exceedences were between 22 and 24 degrees C. A complete set of frequency tables of water temperatures at Parma is located in Appendix C.

### Air Temperatures

Air temperatures collected at Parma and Caldwell by the University of Idaho Climate Data Center are very useful for describing the daily minimum, average, and maximum air conditions over the river. Figure 5 shows the distinct pattern of both average and maximum air temperutures in the Boise River valley, a pattern that is mimicked in water temperature data.

Figure 5. Long Term Monthly Air Temperatures at Parma




The air temperatures associated with maximum water temperatures greater than 22 degrees C at Parma are on average about 12.7 warmer than the air temperatures associated with days on which the maximum water temperatures are less than 22 degrees C. Table 7 shows the typical daily maximum air temperatures associated with exceedence and non-exceedence water temperatures at Parma. Figure 6 shows the positions of monthly average air temperature during the 1990s relative to the long term average monthly air temperatures at Parma (1961-1990).

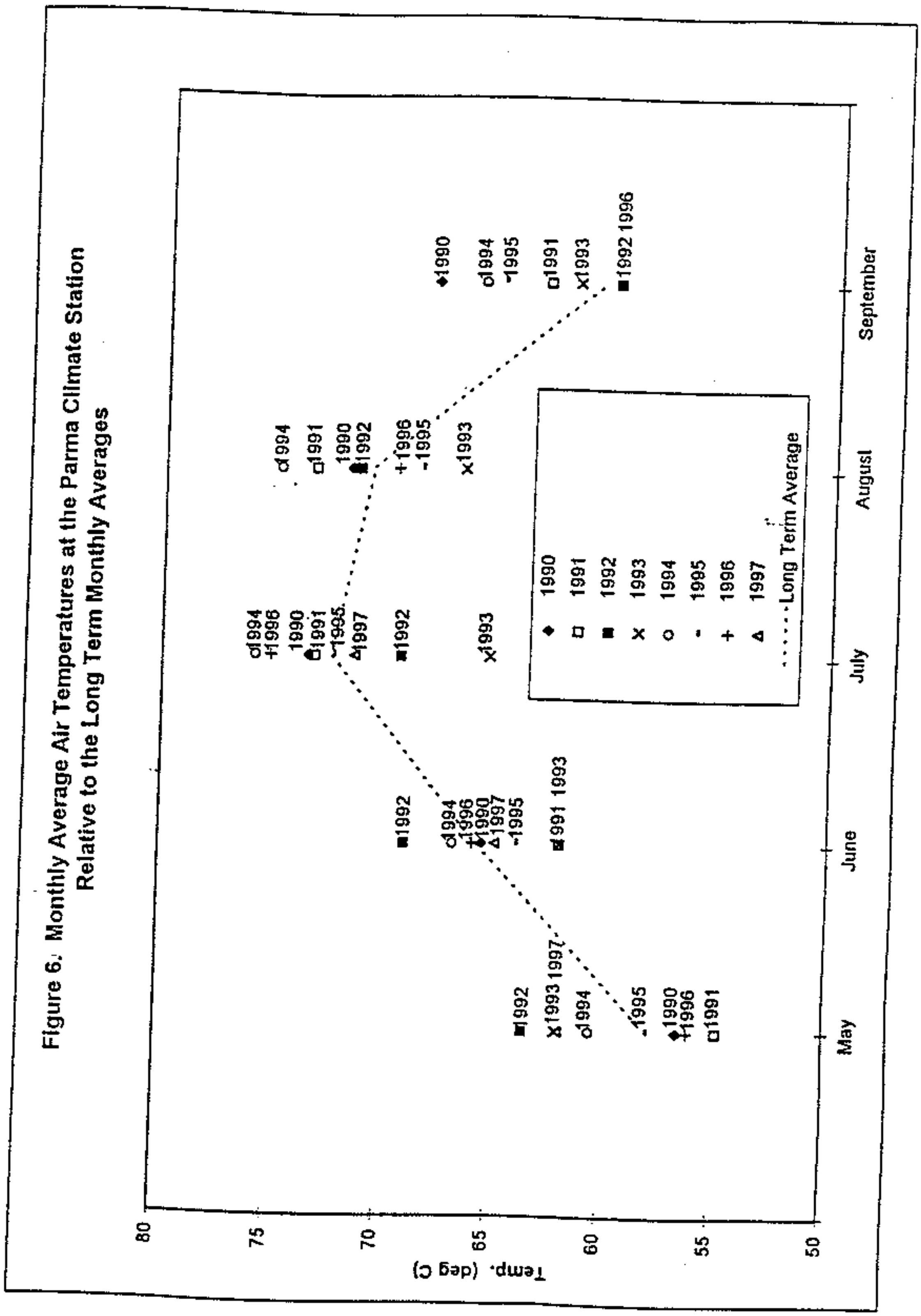



**Figure 6. Monthly Average Air Temperatures at the Parma Climate Station Relative to the Long Term Monthly Averages**

**Table 7. Averages of Daily Maximum Air Temperatures at Parma, 1987-1997**

| Month | Air Temperatures (deg F) When Max. Water Temperatures are <= 22 deg. C | Air Temperatures (deg F) When Max. Water Temperatures Exceed 22 deg. C |
|---|---|---|
| May | 74 | 88 |
| June | 77 | 90 |
| July | 80 | 93 |
| August | 84 | 94 |
| September | 81 | 95 |

## Flow Conditions

The flows in the Boise River at Parma were below average during most of the years between 1987 and 1997. The late 1980s and early 1990s were years of well below average flows. Flows were mixed above and below monthly averages in 1995, while 1996 was the first year since 1987 that was above the period of record annual average, based on water years. During years such as 1992 and 1994 when flows were well below average, water temperatures were in excess of state criteria more often, and by wider margins than in wet years like 1996. However, it is important to note that water temperatures at Parma exceeded state maximum and average criteria even when flows were well above average. The average number of daily maximum criteria exceedences in July of below average flow years is 27, while the average for above average flow years is only 9 exceedences. Table 8 displays monthly average flows, and indicates the position of the flows relative to long term averages for the Parma gage.

**Table 8. Average Discharge at Parma Gage 13213000, cubic feet per second (cfs) Period of record: 1971 to 1996**

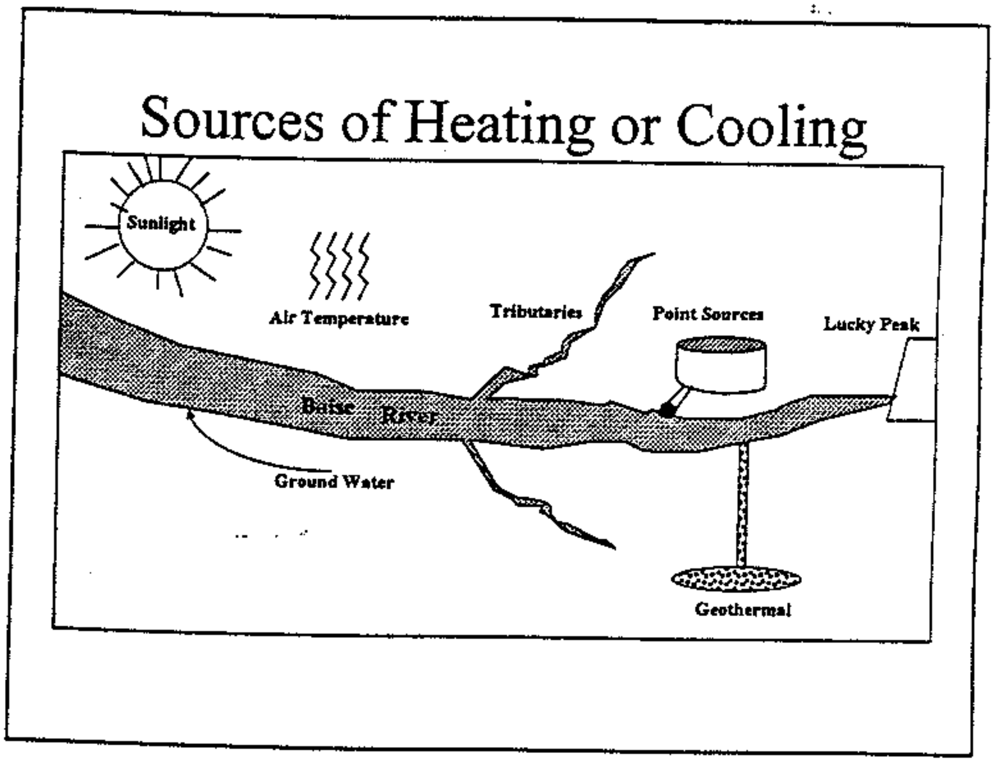
**BOLD** = Flow larger than average *Italics* = Flow less than average

| Water Year | April 2920 cfs | May 3011 cfs | June 2072 cfs | July 983 cfs | Aug 757 cfs | Sept 982 cfs | Annual Avg. 1628 cfs |
|---|---|---|---|---|---|---|---|
| 1997 | **6835** | **5255** | **3938** | **1358** | **1542** | **1474** | N/A |
| 1996 | **5625** | **5010** | **4217** | **1064** | **1132** | **1117** | **2949** |
| 1995 | *1606* | **4551** | **2591** | **2369** | **1028** | **1070** | *1473* |
| 1994 | *483* | *806* | *521* | 700 | *596* | *400* | *723* |
| 1993 | *1705* | **3791** | *1440* | **1010** | **922** | *878* | *1145* |
| 1992 | *243* | *276* | *316* | 282 | *187* | *184* | *459* |
| 1991 | *538* | *781* | *671* | 534 | *424* | *550* | *684* |
| 1990 | *357* | *714* | *554* | 406 | *519* | *633* | *662* |
| 1989 | **3392** | *1178* | *564* | 578 | *739* | **989** | *1013* |
| 1988 | *432* | *506* | *481* | 301 | *306* | *416* | *594* |
| 1987 | *283* | *658* | *559* | 503 | *523* | *685* | *880* |

# Source Analysis

## Potential Sources

The water temperature in the Boise River is controlled by both natural and human factors. The sources affecting temperature are displayed in Figure 7, below. Activities that affect water temperature include the cold water released from Lucky Peak Reservoir, point source discharges of water, and geothermal flows. Tributaries that flow into the Boise River during the summer time are in many cases influenced by irrigation activity, and carry significant quantities of return flow and intercepted shallow groundwater. The tributaries may provide either heating or cooling effects on the river, depending on their temperatures relative to the mainstem. Sunlight that strikes the water is a source of heating, as is the air temperature during the summertime. Ground water is generally neutral or a source of cooling during the summer.




### Lucky Peak Dam Release

The water that is released from the reservoir is drawn from deep within the reservoir, and thus is a relatively constant, cold temperature. During the summertime irrigation season, water leaving the reservoir ranges from about 12 to 14 degrees Celsius all day, every day. The release temperature is a function of the pool depth maintained to support irrigation supplies and location of the penstocks deep in the pool.

### Waste Water Treatment Plant Temperatures

The municipal waste water treatment plants that discharge to a segment of the Boise River that is listed for temperature are the City of Middleton and the City of Caldwell. The City of Nampa treatment plant discharges to Indian Creek well upstream of the confluence with the Boise River, and thus is incorporated into the temperature of Indian Creek at its mouth. The current design capacity of the Caldwell plant is 12.04 cubic feet per second, and planned expansions will increase the monthly average flow to 13.12 cfs in the future. Holladay Engineering supplied monthly data to characterize the flow and temperature of the Middleton effluent. The City of Caldwell provided daily flow and temperature data. The temperature characteristics of the effluents are described below in

### Geothermal Discharge in Boise

Geothermally heated water enters the Boise River from a discharge point just upstream of the diversion dam for the Settlers Canal, near the Americana Boulevard Bridge. The discharge is typically quite small, flowing less than one half of one cubic foot per second. The temperature of the geothermal water is typically between about 90 and 120 degrees F (32.2 and 48.9 deg. C respectively). The geothermal water now released into the Boise River will be re-injected into the ground water system by the end of 1998, eliminating the flow of heated water.

### Tributaries to the Boise River

For this analysis, tributaries are considered to be distinct sources of heat load to the river, because many of the tributaries flow during the summer months due to irrigation activities. Though sunlight and air temperature affect the tributaries, their flows are examined as inputs that are separate from the net effect of the atmosphere on the Boise River itself. Many of the tributaries carry a blend of surface runoff from fields, water distributed from canals, and shallow groundwater. Tributaries vary in their typical temperatures. As described in the Available Data section, the USGS monitored water temperatures hourly in Dixie Drain, Conway Gulch, and East Hartley Gulch from 7/18/96 to 9/5/96. Conway Gulch is generally about the same temperature as, or slightly cooler than the Boise River near Notus. Dixie Drain and Hartley Gulch may often be warmer than the river water during the summertime. Graphs of the 1996 summer temperatures in the tributaries are shown in Figures 8, 9, and 10 below.

Figure 8. East Hartley Gulch Water Temperatures, Summer 1996

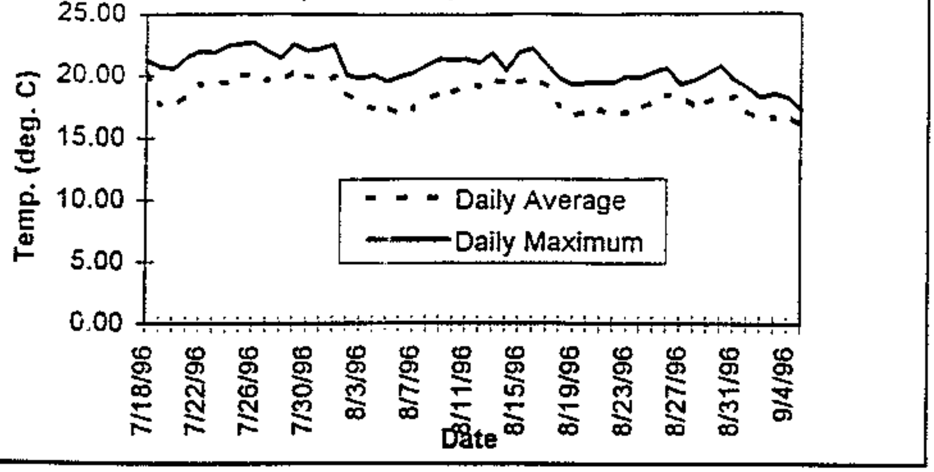



Figure 9. Conway Gulch Water Temperatures, Summer 1996

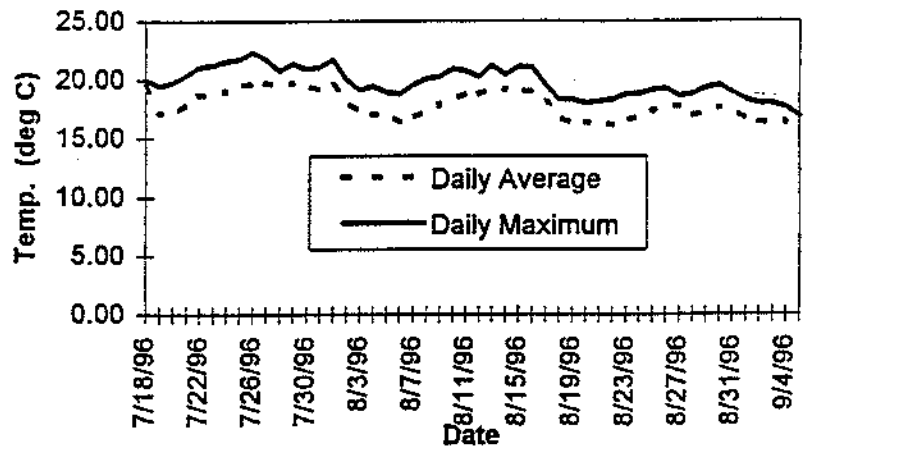
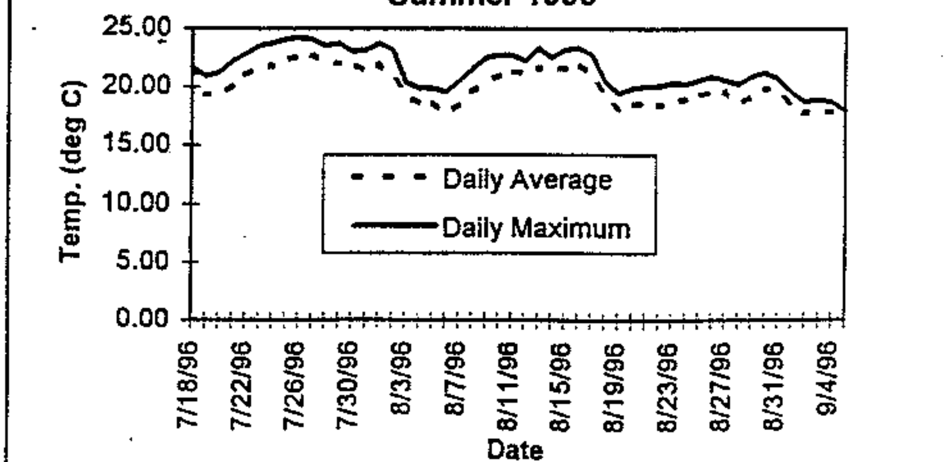



Figure 10. Dixie Drain Water Temperatures, Summer 1996



### Net Atmospheric Effect

The atmosphere affects the temperature of the Boise River in two ways. Sunlight striking the water transfers energy from light waves to heat in the water. The air itself, when it is warmer than the water, transfers heat energy to the water. The analysis lumps the two effects, sunlight and air temperature, into one "net" atmospheric input. During the summer months, daily high air temperatures over the lower Boise River valley may regularly be in the high 90s to over 100 degrees Fahrenheit. On many days during the summer, the average air temperature for a day may be warmer than the average daily water temperature in the river, creating a flux of energy into the river water throughout the entire day.

## Methodology

The analysis of temperature conditions and contributing sources of heat is an empirical review describing the river in recent years and a characterization of the relative contributions of different heat sources. The analysis is empirical because sufficient data are available to characterize water temperatures in the Boise River across a wide range of flow and air temperature conditions from 1987 to the present. The cold water biota criteria during the summer months are the foci of all calculations, since the majority of criteria exceedences occur in July and August. Winter months are not included, since no salmonid spawning criteria exceedences are evident in the data for the reach from Star to Caldwell.

Two general conditions, average and low flow, are included in the analysis. The average year is 1996, since flows are modestly above the long term averages for the summer months of most interest (July and August). The average year, 1996, is also a data rich year, with hourly temperature available in the river and selected tributaries. A year with lower flows, higher air temperatures, and more water temperature criteria exceedences is 1994, the year which serves as a case example of a problematic year. The climate records for the summer of 1994 reveal prolonged periods with no precipitation and daily high air temperatures over 95 degrees F.

In each example year, temperature and flow data in the Boise River, and its tributaries are mixed longitudinally and compared with measured temperatures in the river. Two reaches of the river are analyzed, as follows: Middleton to Caldwell, and Caldwell to Parma. The reach breaks are based on the availability of gage flow and temperature data. The net flow at the end of a given river reach is the result of river flow, point source inputs, tributary inputs, and diversions. Any residual difference between the calculated flow and a gaged flow is entered into the calculations as groundwater.

Over the length of a reach, a spreadsheet model calculates the water temperature after tributaries and point sources are mixed with the river. The difference between the measured temperature at the end of a reach and the calculated temperature is the empirical derivation of the net atmospheric heat input. For each river reach, sources are analyzed based on both daily maximum and daily average temperatures. The discussion below provides a detailed description of the equations, data, and assumptions used in the analysis.

### Mixing Equation

The temperature analysis uses available flow, water temperature, and tributary temperature data to identify the impact of surface water inflows on the Boise River. Point source discharges of water are also included as inputs. The goal of the analysis is to assess the relative impact of temperature inputs on the river water temperature. The temperature of the Boise River itself as it passes Middleton is the first "source" of temperature to the river downstream of Middleton. Thereafter, the accumulated temperature in the Boise River is calculated by mixing in point sources, groundwater, and tributaries. The calculated river temperatures are compared to measured values. Any temperature increase that cannot be attributed to point sources, groundwater, or tributaries is an atmospheric effect. The equation used to model surface water inputs of temperature is a standard temperature mixing equation, shown below:

$$Tm = [(Q*T) + (Qi*Ti)] / (Q + Qi)$$

Where

- Q = mainstem river flow, cfs
- T = mainstem river temperature, deg. C
- Qi = tributary flow, cfs
- Ti = tributary temperature, deg. C
- Tm = average mainstem temperature after mixing, deg. C

Source:

Lee, Richard, Forest Hydrology, New York: Columbia University Press, 1980, p 238.

### Example Calculation

Example day: 7/18/96, From Caldwell to Conway Gulch, 7.9 river miles, based on daily maximum temperatures

| | | |
|---|---|---|
| A | Per mile ground water flow | = 20cfs |
| B | Ground water temperature | = 16 deg C |
| C | River flow at Caldwell | = 803cfs |
| D | River temperature at Caldwell | = 20.0 deg C |

| | | |
|---|---|---|
| E | Eureka #2 Diversion flow | = -118 cfs |
| F | Upper Center Point Diversion flow | = -22 cfs |
| G | McManus diversion flow | = -3 cfs |
| H | Bowman diversion flow | = -8 cfs |
| I | Lower Center Point diversion flow | = -16 cfs |
| J | Conway Gulch flow | = 72 cfs |
| K | Conway Gulch Temperature | = 19.52 deg C |

Temperature After Conway Gulch is Mixed Into the River:

(((C+(E+F+G+H+I))*D)+((A*7.9)*B) + (J*K)) / (C+(E+F+G+H+I) + J +(a*7.9))

Mixed temperature = 19.23 deg. C

Since Conway Gulch is slightly cooler than the river water, but its flow is modest, only a very slight change in temperature occurs. In this example, Conway Gulch has a slight cooling influence on the river. Note that the per mile ground water flow, 20 cfs, is multiplied by 7.9 miles, and is then multiplied by 16 deg. Celsius. In this example, both Conway Gulch and the ground water exert cooling influences on the surface water, and the river temperature after the inflows of groundwater and Conway Gulch is slightly less than at Caldwell.

## Statement of Assumptions

Several important assumptions are included in the analysis. The assumptions are listed and explained below.

- Ground Water Flow
  The ground water flow is assumed to be the remaining flow after all published inputs and diversions are counted along the length of each of the four reaches analyzed. Groundwater inputs are assumed to enter the river evenly per mile of length in a reach. Thus the total groundwater flow needed to balance a reach between USGS gages is divided by the length of the reach in miles.

- Ground Water Temperature
  The ground water temperature used in the analysis is 16 degrees Celsius. The derivation of the ground water temperature is found below.

- Water Temperatures in Tributaries without Monitoring
  For tributaries that do not have daily water temperature records, the water temperatures measured in a similar tributary are applied. This assumption is most critical in the Middleton to Caldwell reach, where ONLY East Hartley Gulch has daily temperature records. Because East Hartley Gulch has little shade for much of its length, and was warmer than the Boise River during 1996,

the application of its temperatures to all of the other tributaries between Middleton and Caldwell is a reasonable and conservative assumption. The tributaries covered by the East Hartley Gulch data are Mason Creek, Mason Slough, West Hartley Gulch, Mill Slough, and Willow Creek.

- Indian Creek Temperautres
  Indian Creek temperatures are assumed to be the same as those measured downstream of the Nampa wastewater treatment plant. Weekly temperatures are measured by the treatment plant are extended for six days, up to the next weekly measurement.

- Point Source Temperatures
  Two point source discharges enter the Boise River directly, the City of Middleton and the City of Caldwell. The Nampa effluent enters Indian Creek well upstream of its confluence with the Boise River, and is thus lumped into the Indian Creek water temperature. Based on 1996 monthly monitoring data, the Middleton treatment plant water temperatures range from 19.4 degrees C to 20.9 degrees C during July, August, and September. The data from those months are applied to the analysis. Flows from the treatment plant range from 0.52 cfs to 1.31 cfs, again based upon July, August, and September data from 1996. Data to characterize the Middleton WWTP plant during 1994 are not available. Though the data available for the Middleton treatment plant are sparse, the small size of its discharge means that the data are sufficient for this analysis. The Caldwell treatment plant monitors effluent flow and temperature daily. The analysis makes use of the daily data from both 1994 and 1996. Thus the representation of the Caldwell discharge in the analysis is very accurate.

- Mixing
  The analysis assumes uniform mixing of inputs to the river, and does not attempt to quantify variability of water temperatures laterally or through the depth of the river.

### Ground Water Characterization

Flows in the spreadsheet are balanced between the Middleton and Caldwell USGS gage data, using known tributary inputs and water diversions. After all inputs and diversions are entered between the gages, the residual flow difference between Middleton and Parma is the ground water input, and is assumed to enter the river evenly on a per mile basis between the two gages.

The temperature of the ground water in the model is 16 degrees C, or 60.8 degrees Fahrenheit. An analysis of monitoring from wells of less than 100 feet in depth shows a range of temperatures. To apply a conservative assumption to the model, the 95th percentile ground water temperature from wells less than 100 feet, 16 degrees C, is used in all calculations. The well data are summarized in Appendix B of

> Boyle, Linda, Sabrina Nicholls, and Deb Parliman, Ground Water Study of the Lower Boise River Valley, Ada and Canyon Counties, Idaho, Water Quality Status Report No. 118, Idaho Department of Health and Welfare, DEQ, May 1996.

### Average Year Analysis, 1996

For the analysis, 1996 is an amenable year because hourly temperatures are on record for Eckert Road, Glenwood Bridge, Middleton, Caldwell, Parma, East Hartley Gulch, Conway Gulch, and Dixie Drain. The data, matched with daily flow information, provide an excellent way in which to analyze thermal inputs on many days during July, all of August, and the first five days of September. The averages of the daily analyses represent the typical impacts of various sources. The assumptions listed above apply to this simulation.

### Hot, Low Flow Year Simulation (1994)

The year 1994 is an example of time in which summer air temperatures on record are very hot for prolonged periods, and river flows on record are less than the long term monthly averages. Like the 1996 analysis, the hot year analysis centers on July and August. To generate a suitable set of temperature data for 1994, daily values measured in 1996 are scaled upwards to reflect warmer conditions experienced in 1994. The 1994 simulation uses the same structure as the 1996 simulation, but adjusts all flows according to published records for 1994, and inserts warmer water temperatures as described below.

### Scaling Technique

Unlike 1996, daily water temperature data from 1994 are available only at the Parma gage site. To analyze temperature conditions in 1994, the daily temperature measurements from 1996, both in the river and in tributaries, are scaled upward to generate a data set for 1994. The percentage of the increase varies by day, and is based on the difference between the water temperatures measured at Parma in 1994, and in 1996.

To scale 1996 measured temperatures upward for the 1994 simulation, the measured daily maximum temperatures at Parma during 1996 are compared to the 1994 daily maximum temperatures measured at the same location to create a multiplier for the temperatures at other sites. The relationship between the 1994 and 1996 temperatures at Parma, on a daily basis, is assumed to be applicable to tributaries and other mainstem Boise River locations. The multiplier, expressed as a

percent, is defined by the following equation:
multiplier = (1994 temp, deg. C - 1996 temp, deg. C) / 1996 temp, deg. C * 100

**Analysis Results: Source Contributions**
The analysis of sources shows that during both average flow years and during low flow, hot years, the atmosphere contributes the majority of the temperature increase that occurs in the Boise River. Point source discharges contribute very little heat load to the river in their present configurations. During the summer months, groundwater is either neutral or a cooling influence on the river. Tables 9. And 10 below show splits of temperature inputs between contributing sources (tributaries and point sources) and the net atmospheric input of heat. Each table shows the number of degrees of increase due to a given source along the length of a river reach. Atmospheric inputs are clearly the dominant influence on the water temperature of the river.

**Table 9. Sources of Heat Input - 1996 Daily Conditions**

| Average Change in Temperature, deg. Celsius | 1996 Maximums | 1996 Maximums | 1996 Average | 1996 Average |
|---|---|---|---|---|
| **Location** | **Surface Input** | **Ground Water** | **Surface Input** | **Ground Water** |
| Mill Slough | 0.12 | -0.41 | -0.05 | -0.26 |
| Middleton WWTP | 0.00 | -0.09 | 0.00 | -0.05 |
| Willow Creek | 0.02 | -0.08 | 0.00 | -0.05 |
| Mason Slough & Mason Creek | 0.13 | -0.14 | 0.02 | -0.08 |
| East & West Hartley Gulch | 0.07 | -0.08 | 0.02 | -0.05 |
| Caldwell WWTP | 0.02 | -0.32 | 0.04 | -0.18 |
| Indian Creek | -0.04 | -0.01 | 0.06 | -0.01 |
| NET ATMOS 1 | 1.25 | N/A | 0.92 | N/A |
| Conway Gulch | -0.08 | -0.28 | -0.11 | -0.70 |
| Dixie Drain | 0.41 | -1.09 | 0.38 | -0.18 |
| NET ATMOS 2 | 2.34 | N/A | 2.05 | N/A |

**Table 10. Sources of Heat Input - 1994 Daily Conditions**

| Average Change in Temperature, deg. Celsius | Distance to Location | 1994 MAX | 1994 MAX | 1994 Average | 1994 Average |
|---|---|---|---|---|---|
| **Location** | **Miles** | **Surface Input** | **Ground Water** | **Surface Input** | **Ground Water** |
| Mill Slough | | 0.10 | -0.49 | -0.07 | -0.31 |
| Middleton WWTP | | 0.00 | -0.10 | 0.00 | -0.06 |
| Willow Creek | | 0.04 | -0.07 | 0.03 | -0.03 |
| Mason Slough & Mason Creek | | 0.17 | -0.17 | 0.03 | -0.10 |
| East & West Hartley Gulch | | 0.11 | -0.10 | 0.03 | -0.06 |
| Caldwell WWTP | | 0.00 | -0.49 | 0.06 | -0.29 |
| Indian Creek | | -0.01 | -0.02 | 0.13 | -0.01 |
| **NET ATMOS 1** | | 1.46 | N/A | 1.02 | N/A |
| Conway Gulch | | -0.16 | -1.78 | -0.09 | -0.95 |
| Dixie Drain | | 0.87 | -0.40 | 0.60 | -0.31 |
| **NET ATMOS 2** | | 2.68 | N/A | 1.74 | N/A |

## Evaluation of Tributary Cooling

After analyzing 1994 and 1996 conditions, the effects of cooling the tributaries to the lower Boise River downstream of Middleton are examined using techniques similar to those described above. For 1994 and 1996, all of the water temperatures for tributaries to the Boise River, excluding the Caldwell waste water treatment plant, are gradually reduced to simulate cooling of the inputs to the river. The reduction analysis considers daily average temperatures, since tributary cooling would occur throughout the day.

For Tables 11 and 12:
Top row = degree reduction in average tributary temperature
Bottom row = percent reduction of daily average exceedences at Parma

**Table 11. Daily Average Temperature Reductions**
**All Tributaries Downstream of Middleton**

| **1996** | 5.0 deg C | 6.0 deg C | 7.0 deg C | 8.0 deg C |
|---|---|---|---|---|
| Reduction | 49% | 66% | 78% | 93% |

**Table 12. Daily Average Temperature Reductions**
**All Tributaries Downstream of Middleton**

| **1994** | 5.0 deg C | 6.0 deg C | 7.0 deg C | 8.0 deg C | 9.0 deg C |
|---|---|---|---|---|---|
| Reduction | 38% | 49% | 64% | 71% | 80% |

To eliminate daily average exccedences at Parma would require reductions, for all tributaries downstream of Middleton, of about 8.0 degrees Celsius in 1996 and greater than 9.0 degrees Celsius in 1994. The results show that the reductions needed in tributary water temperatures are very large, and unlikely to be achievable. The result is not unexpected given that the atmosphere drives temperature conditions in the river more strongly than do the tributaries.

## Conclusions

### Cold Water Biota Criteria

Water temperature criteria for cold water biota are not fully supported during the summer months from Middleton to the mouth of the Boise River. Water temperatures in excess of the state criteria occur occasionally at Middleton and Caldwell, and very frequently in the vicinity of Parma. The majority of criteria exceeding water temperatures occur in June, July, and August. A few exceedences may occur during May and September of especially hot years. Both the daily maximum criterion and the maximum daily average criterion for water temperature with respect to cold water biota are not met downstream of Middleton.

### Sources of Heat Load to the River

The climate of the lower Boise river valley has a strong controlling influence on the temperature of the water in the Boise River during the summer months. Other inputs of heat load to the river, such as tributaries and waste water treatment plants, contribute only modest percentages of the total temperature increases that occur in the river.

## Recommendations

To be completed pending loading analysis.

# Appendix A

## Available Water Temperature Data for the Mainstem of the Boise River

| Agency | Station Name | Years | Frequency | Reported Data | Comments |
|---|---|---|---|---|---|
| USGS | Middleton | 7/18/96 to 9/5/96 and 4/15/97 to 9/4/97 | Hourly | Water Temp, deg C | Diurnal, HOBO temp. logger |
| USGS | Middleton | 11/91 to the present | Bi - monthly | Water Temp, deg C | Synoptic monitoring |
| USGS | Caldwell | 7/18/96 to 9/5/96 and 6/28/97 to 9/1/97 | Hourly | Water Temp, deg C | Diurnal, HOBO temp. logger |
| USGS | Parma | 7/18/96 to 9/5/96 and 4/15/97 to11/11/97 | Hourly | Water Temp, deg C | Diurnal, HOBO temp. logger |
| USGS | Parma | Water Year 95 | Daily | Min and Max Temp, deg C | July missing 11 days, August blank, September blank |
| USGS | Parma | Water Year 94 | Daily | Min and Max Temp, deg C | Complete data |
| USGS | Parma | Water Year 93 | Daily | Min and Max Temp, deg C | September missing 2 days |
| USGS | Parma | Water Year 92 | Daily | Min and Max Temp, deg C | Complete data |
| USGS | Parma | Water Year 91 | Daily | Min and Max Temp, deg C | October blank, November blank, December blank, January missing 29 days |
| USGS | Parma | Water Year 90 | Daily | Min and Max Temp, deg C | October missing 11 days, November missing 16 days, August missing 29 days, September blank |

| | | | | | |
|---|---|---|---|---|---|
| USGS | Parma | Water Year 89 | Daily | Min and Max Temp, deg C | February missing 10 days, March missing 10 days, July missing 4 days, August missing 11 days, September missing 7 days |
| USGS | Parma | Water Year 88 | Daily | Min and Max Temp, deg C | March missing 18 days, April missing 20 days |
| USGS | Parma | Water Year 87 | Daily | Min and Max Temp, deg C | June blank, April missing 10 days, May missing 3 days |

# Appendix B

## Water Temperatures at Selected Lower Boise River Sites

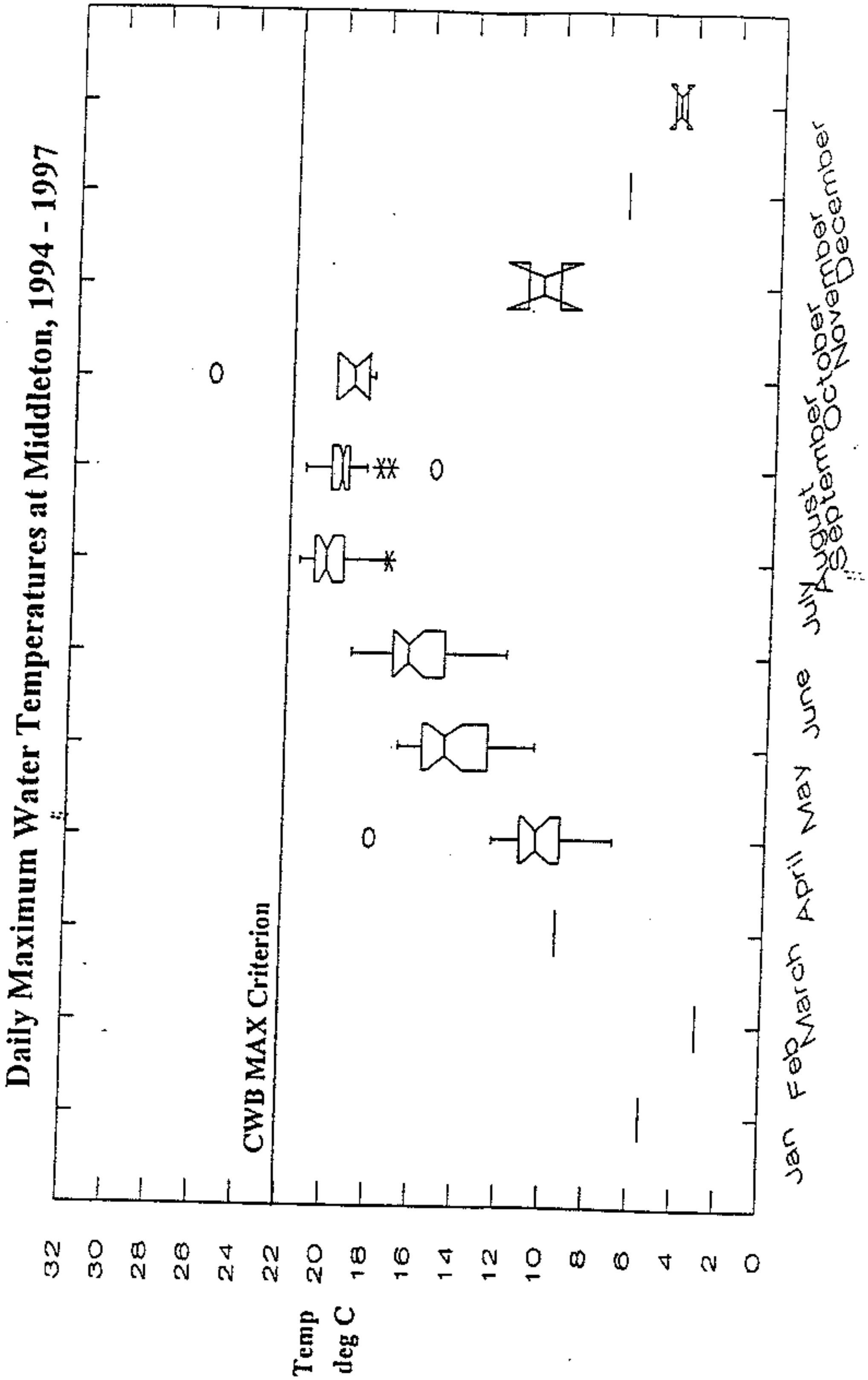

Daily Maximum Water Temperatures at Middleton, 1994 - 1997
CWB MAX Criterion
Temp deg C
32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
Jan Feb March April May June July August September October November December

Figure 1.

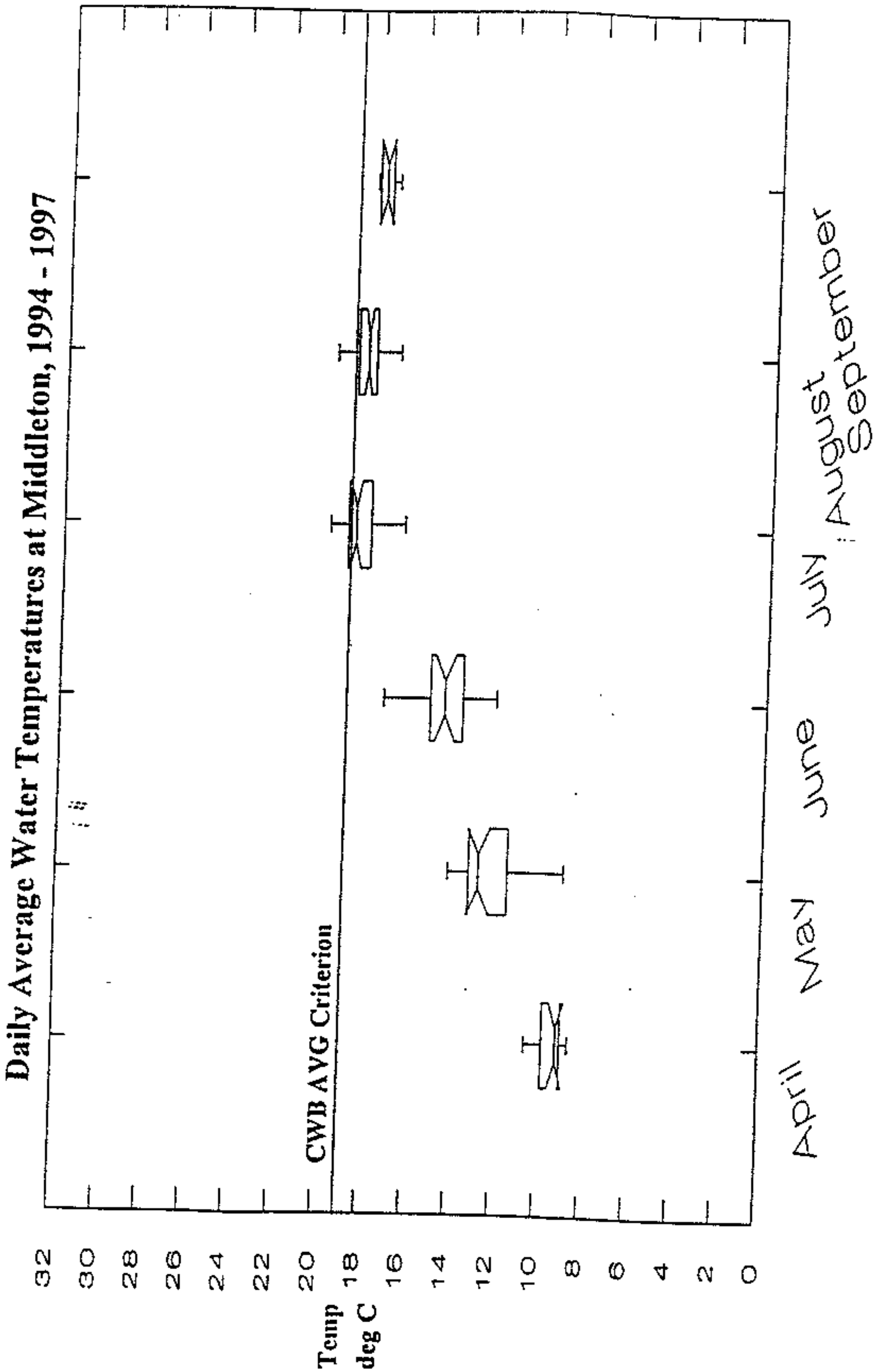

Daily Average Water Temperatures at Middleton, 1994 - 1997
CWB AVG Criterion
Temp
deg C
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
April
May
June
July
August
September

Figure 2.

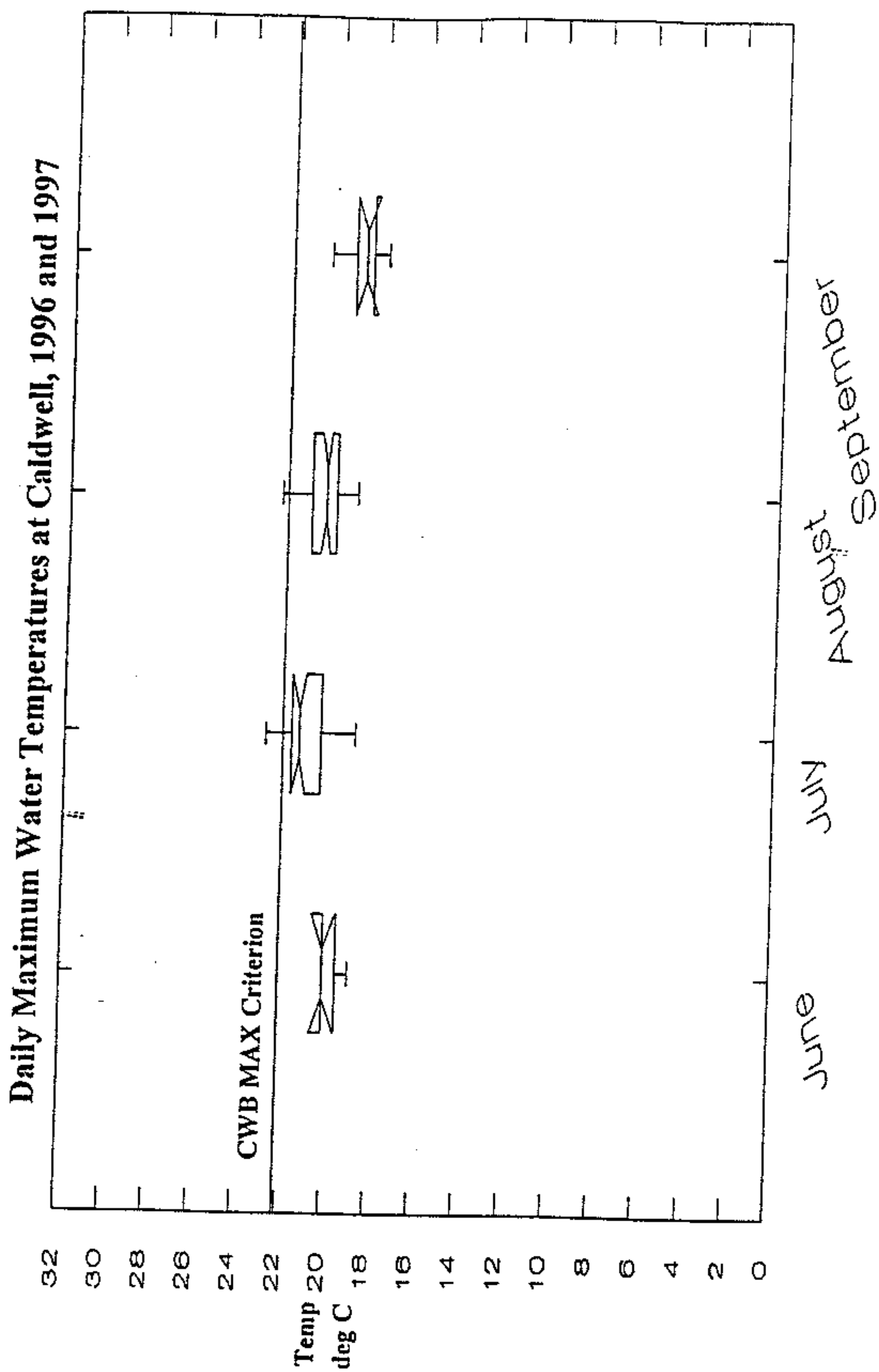

Daily Maximum Water Temperatures at Caldwell, 1996 and 1997
CWB MAX Criterion
Temp deg C
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
June
July
August
September

Figure 3.

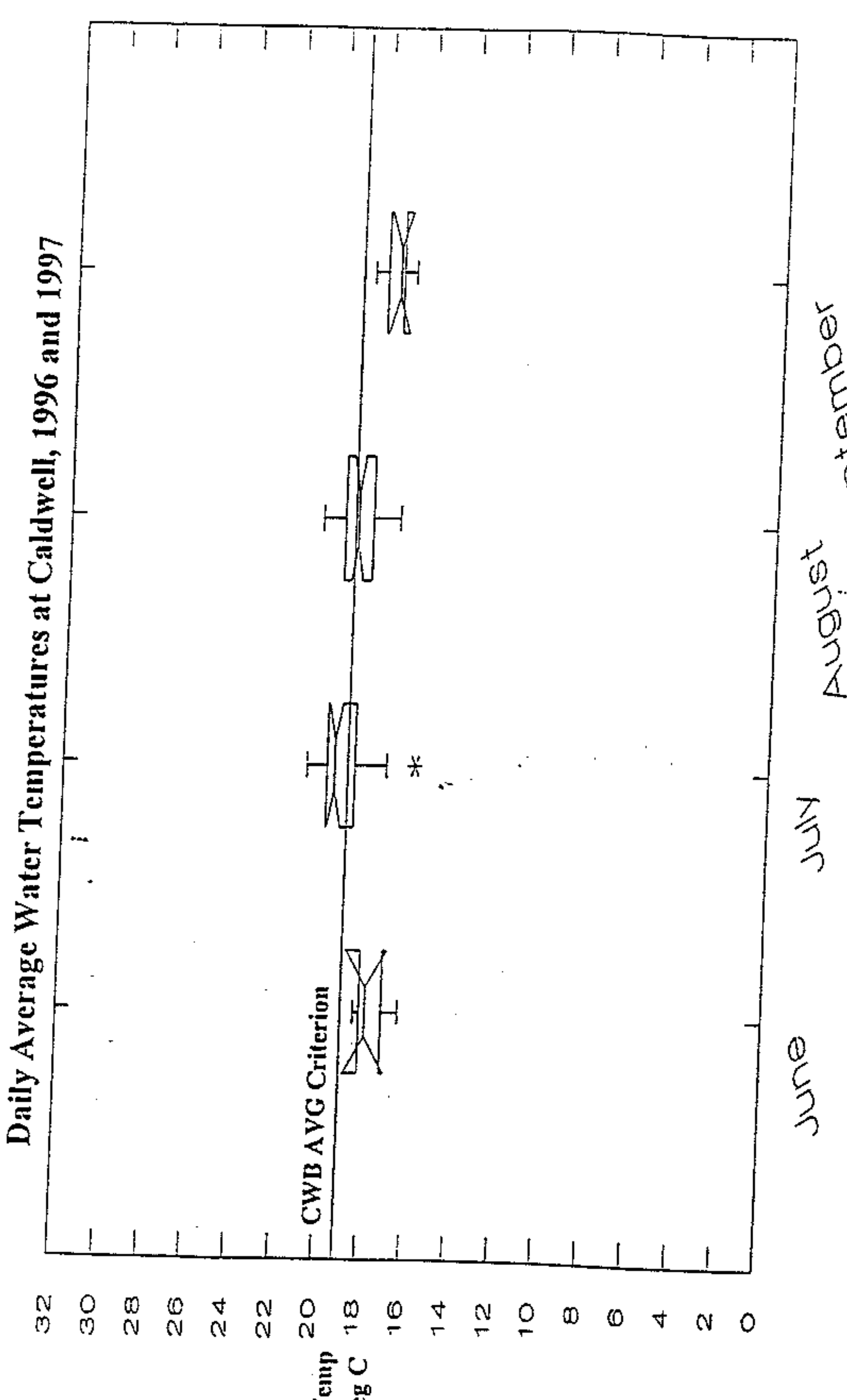
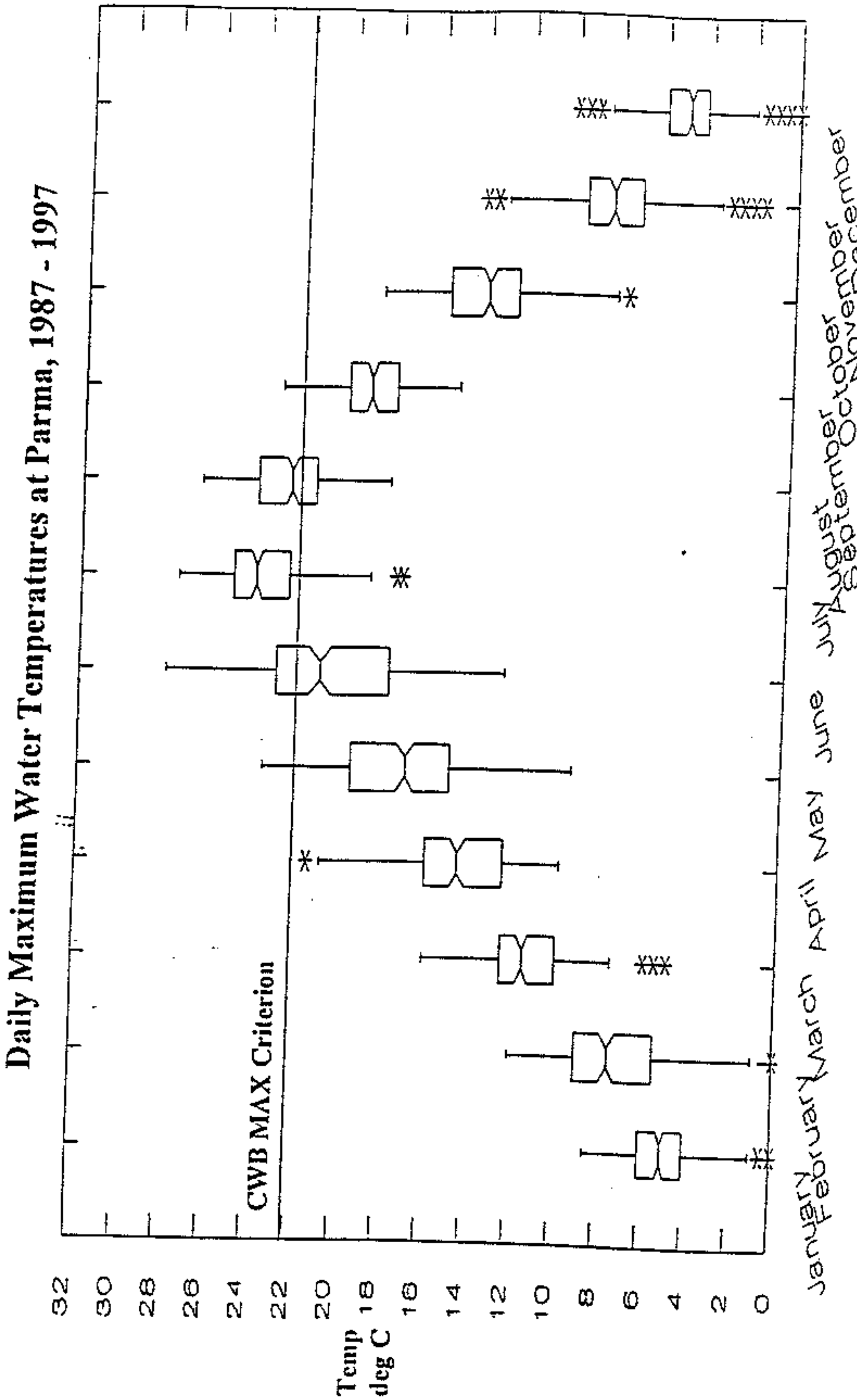
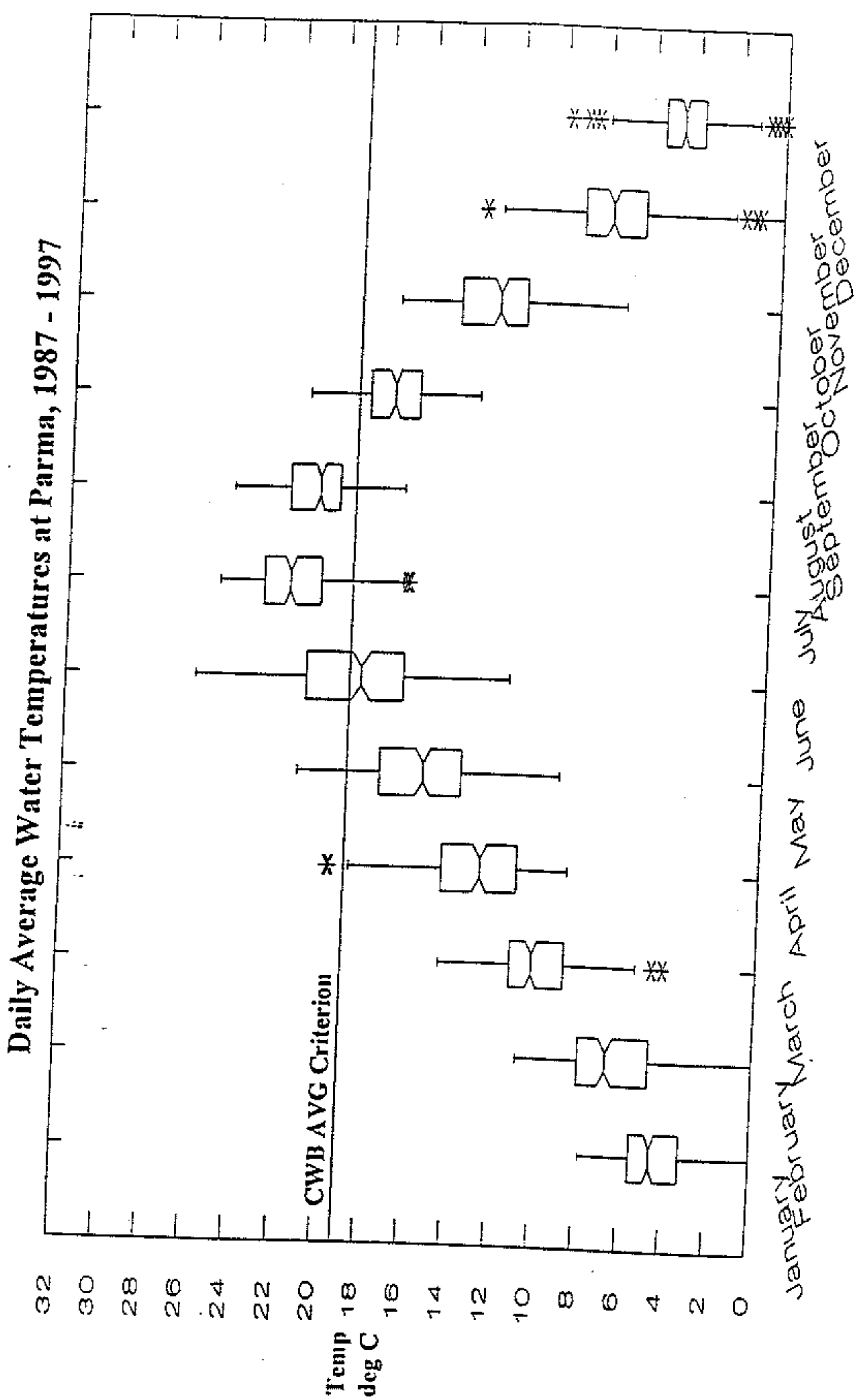

Daily Average Water Temperatures at Caldwell, 1996 and 1997
CWB AVG Criterion
Temp deg C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
June
July
August
September

Figure 4.



Daily Maximum Water Temperatures at Parma, 1987 - 1997
CWB MAX Criterion
Temp
deg C
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December


Figure 5.



Daily Average Water Temperatures at Parma, 1987 - 1997
CWB AVG Criterion
Temp deg C
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
January
February
March
April
May
June
July
August
September
October
November
December


Figure 6.

# Appendix C

## Frequency Tables of Water Temperatures at Parma

1987 Daily Maximum Water Temperatures

| Temp Category deg C | May * | June | July * | August | September |
|---|---|---|---|---|---|
| 0 - 22 | 21 | ND | 10 | 16 | 28 |
| 22 - 23 | 5 | ND | 3 | 7 | 2 |
| 23 - 24 | 2 | ND | 5 | 5 | |
| 24 - 25 | | ND | 6 | 3 | |
| 25 - 26 | | ND | 6 | | |
| 26 - 27 | | ND | | | |
| 27 - 28 | | ND | | | |
| 28 - 29 | | ND | | | |
| 29 - 30 | | ND | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1988 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July * | August | September |
|---|---|---|---|---|---|
| 0 - 22 | 28 | 13 | 1 | 9 | 30 |
| 22 - 23 | 3 | 2 | 2 | 11 | |
| 23 - 24 | | 2 | 5 | 9 | |
| 24 - 25 | | 3 | 7 | 2 | |
| 25 - 26 | | 5 | 14 | | |
| 26 - 27 | | 2 | 2 | | |
| 27 - 28 | | 3 | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

1989 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July * | August * | September * |
|---|---|---|---|---|---|
| 0 - 22 | 31 | 9 | 1 | 13 | 22 |
| 22 - 23 | | 11 | 1 | 4 | |
| 23 - 24 | | 9 | 8 | 2 | |
| 24 - 25 | | 1 | 10 | 1 | |
| 25 - 26 | | | 6 | | |
| 26 - 27 | | | 1 | | |
| 27 - 28 | | | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1990 Daily Maximum Water Temperatures

| Temp Category deg C | May | June * | July | August * | September |
|---|---|---|---|---|---|
| 0 - 22 | 31 | 15 | 4 | | ND |
| 22 - 23 | | 3 | 2 | | ND |
| 23 - 24 | | 1 | 3 | | ND |
| 24 - 25 | | 1 | 10 | 2 | ND |
| 25 - 26 | | 6 | 5 | | ND |
| 26 - 27 | | 3 | 6 | | ND |
| 27 - 28 | | | 1 | | ND |
| 28 - 29 | | | | | ND |
| 29 - 30 | | | | | ND |

*Incomplete Record ND = No Data Blank Square = no occurrences

1991 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July | August | September |
|---|---|---|---|---|---|
| 0 - 22 | 31 | 28 | | 2 | 28 |
| 22 - 23 | | 2 | 1 | 8 | 2 |
| 23 - 24 | | | 6 | 9 | |
| 24 - 25 | | | 13 | 10 | |
| 25 - 26 | | | 11 | 2 | |
| 26 - 27 | | | | | |
| 27 - 28 | | | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1992 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July | August | September |
|---|---|---|---|---|---|
| 0 - 22 | 27 | 10 | 2 | 10 | 28 |
| 22 - 23 | 3 | 4 | 8 | | 2 |
| 23 - 24 | 1 | 8 | 8 | 3 | |
| 24 - 25 | | 3 | 7 | 10 | |
| 25 - 26 | | 3 | 6 | 6 | |
| 26 - 27 | | 1 | | 2 | |
| 27 - 28 | | 1 | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1993 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July | August | September * |
|---|---|---|---|---|---|
| 0 - 22 | 31 | 26 | 29 | 25 | 28 |
| 22 - 23 | | 2 | 2 | 4 | |
| 23 - 24 | | 2 | | 2 | |
| 24 - 25 | | | | | |
| 25 - 26 | | | | | |
| 26 - 27 | | | | | |
| 27 - 28 | | | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1994 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July | August | September |
|---|---|---|---|---|---|
| 0 - 22 | 29 | 15 | 2 | 8 | 30 |
| 22 - 23 | 2 | 6 | 7 | 6 | |
| 23 - 24 | | 2 | 9 | 8 | |
| 24 - 25 | | 3 | 8 | 6 | |
| 25 - 26 | | 4 | 5 | 3 | |
| 26 - 27 | | | | | |
| 27 - 28 | | | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1995 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July * | August | September |
|---|---|---|---|---|---|
| 0 - 22 | 31 | 30 | 2 | ND | ND |
| 22 - 23 | | | | ND | ND |
| 23 - 24 | | | | ND | ND |
| 24 - 25 | | | | ND | ND |
| 25 - 26 | | | | ND | ND |
| 26 - 27 | | | | ND | ND |
| 27 - 28 | | | | ND | ND |
| 28 - 29 | | | | ND | ND |
| 29 - 30 | | | | ND | ND |

*Incomplete Record ND = No Data Blank Square = no occurrences

1996 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July | August | September * |
|---|---|---|---|---|---|
| 0 - 22 | ND | ND | 2 | 18 | 5 |
| 22 - 23 | ND | ND | 2 | 6 | |
| 23 - 24 | ND | ND | 4 | 5 | |
| 24 - 25 | ND | ND | 5 | 2 | |
| 25 - 26 | ND | ND | 1 | | |
| 26 - 27 | ND | ND | | | |
| 27 - 28 | ND | ND | | | |
| 28 - 29 | ND | ND | | | |
| 29 - 30 | ND | ND | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

1997 Daily Maximum Water Temperatures

| Temp Category deg C | May | June | July | August | September * |
|---|---|---|---|---|---|
| 0 - 22 | 31 | 30 | 14 | 22 | 3 |
| 22 - 23 | | | 13 | 7 | |
| 23 - 24 | | | 4 | 2 | |
| 24 - 25 | | | | | |
| 25 - 26 | | | | | |
| 26 - 27 | | | | | |
| 27 - 28 | | | | | |
| 28 - 29 | | | | | |
| 29 - 30 | | | | | |

*Incomplete Record ND = No Data Blank Square = no occurrences

# Appendix D

## Guide To Interpreting Notched Box and Whisker Plots

# Notched Box and Whisker Plot Elements

**Medians**

The median of the data (50% of the values below, 50% of the values above) is represented by the horizontal line inside the box.

**The Notch**

The box has pinched sides, or a "notch" around the median. The notch represents the 95% confidence interval for the median value. When the notch of one box does not overlap with the notch of another box, one can conclude with 95% confidence that a statistically significant difference exists between the medians of the two boxes being compared.

**Hinges**

The lines that form the top and the bottom of the box define the upper and lower quartiles of the data. Twenty-five percent of the values are less than the bottom of the box, and seventy five percent of the values are less than the top line of the box.

**Hspread**

The absolute value of the difference between the upper and lower hinges.

**Whiskers**

The whiskers are the vertical lines above and below the box that represent the values within plus or minus 1.5*Hspread of the upper and lower hinges.

**Fences**

The short horizontal lines at the ends of the whiskers shows the locations of the distances that are 1.5*Hspread greater than the upper and 1.5*Hspread less than the lower hinge.

**Asterisks**

Asterisks represent data that are more than 1.5*Hspread from a hinge, but are within 3*Hspread of a hinge.

**Open Circles**

Open circles represent data that are more than 3*Hspread above or below a hinge.